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MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (STINFO) 16 Mar 2001

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2001-053**
Miller, T.C., "Crack Growth Rates in a Propellant Under Various Conditions" (VuGraphs)

JANNAF 34th Structures & Mechanical Behavior Subcommittee Meeting **(Statement A)**
(Cocoa Beach, FL, 26-30 Mar 01) (Deadline: 26 Mar 2001)

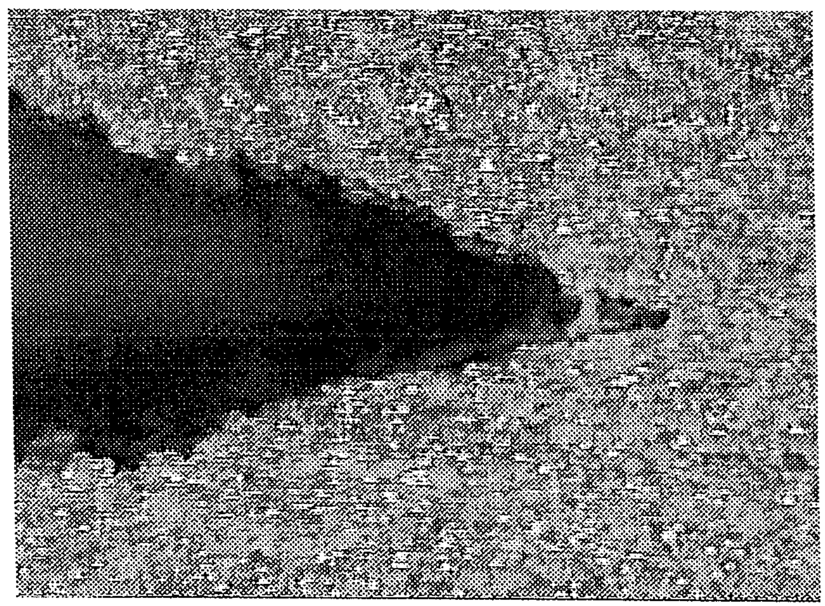
CRACK GROWTH RATES IN A PROPELLANT UNDER VARIOUS CONDITIONS

27 Mar 01

Tim Miller
Engineer
Propulsion Directorate
Air Force Research Laboratory

Introduction

- Cracks develop during manufacturing, handling, and storage of rubbery particulate composites
- During the service life, the cracks may begin to grow, but may still be subcritical because the cracks may grow slower than the burn rate of the propellant
- Results for three types of specimens are described. This is done both at ambient and 1000 psi (6895 kPa) pressure.



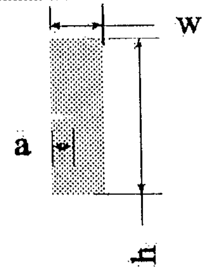
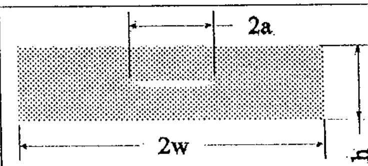
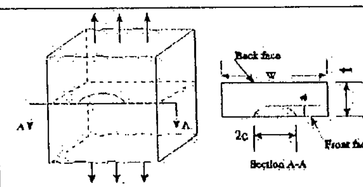
Complications in Propellant Fracture Analysis

- Propellant has unusual properties (time dependence, large deformations, inhomogeneous microstructure) and has not been analyzed as thoroughly as more conventional materials
- Conventional experimental approaches do not always work well because of these properties
- Service conditions vary from long-term low stress conditions caused by thermal loads during storage to short-term high stress conditions caused by pressurization during launch

Experimental Procedure

- Specimen geometries and test matrix
- Test conditions
- Equipment

Specimen Geometries and Test Matrix

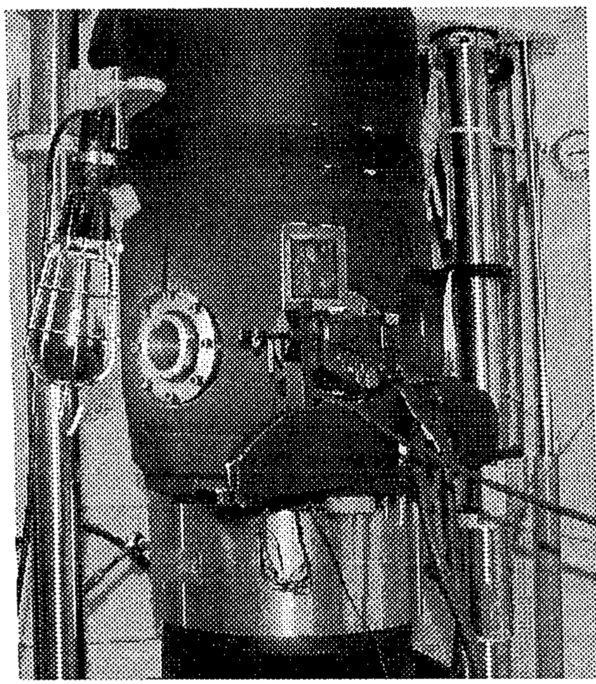
Specimen Type	Figure	Test Conditions
Single edge notched tension	 w = 1 in (25.4 mm) a = 0.1, 0.3 in (2.54, 7.62 mm) h = 3, 5 in (76.2, 127 mm) thickness = 0.2, 0.5, 1.0, 1.5 in (5.08, 12.7, 25.4, 38.1 mm)	Strain rate = 0.067 in/in/min, ambient pressure, 1000 psi (6895 kPa)
Biaxial stress	 2w = 8 in (203.2 mm) 2a = 1.5 in (38.1 mm) h = 2 in (50.8 mm) thickness = 0.2 in (5.08 mm)	Strain rate = 0.100 in/in/min, ambient pressure
Surface cracked	 a = c = 0.4 in (10.16 mm) t = w = 2 in (50.8 mm) height = 2.75 in (69.85 mm)	Strain rate = 0.067 in/in/min, 1000 psi (6895 kPa) pressure

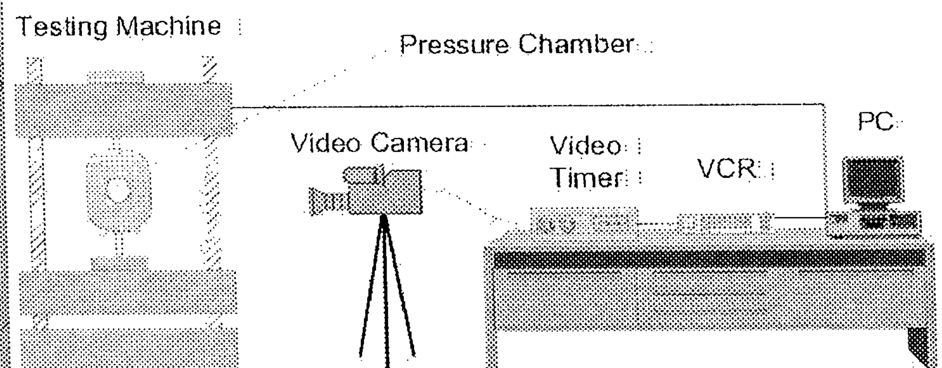
Test Conditions

- Ambient temperature
- Ambient pressure and 6895 kPa pressure (nitrogen gas)
- Constant strain rate tests (0.067 - 0.100 mm/mm/min)

Equipment

- Testing machine
- Pressure test chamber
- Videotape equipment





Fixture Is Used to Apply Uniform Displacement Boundary Conditions

Introduction

Experimental Procedure

Results and Discussion

Summary and Conclusions

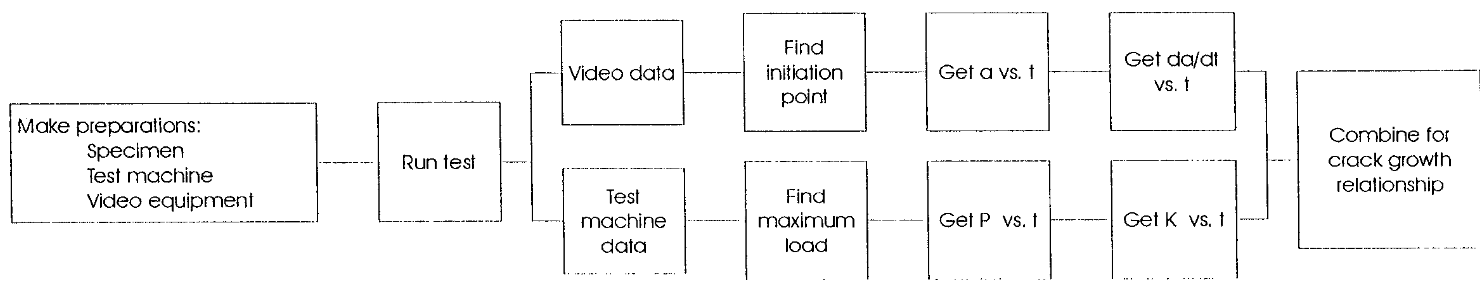
Flowchart for Experimental Procedure

Introduction

Experimental Procedure

Results and Discussion

Summary and Conclusions



Nonsmooth or irregular?

~~Nonuniform~~ Crack Growth

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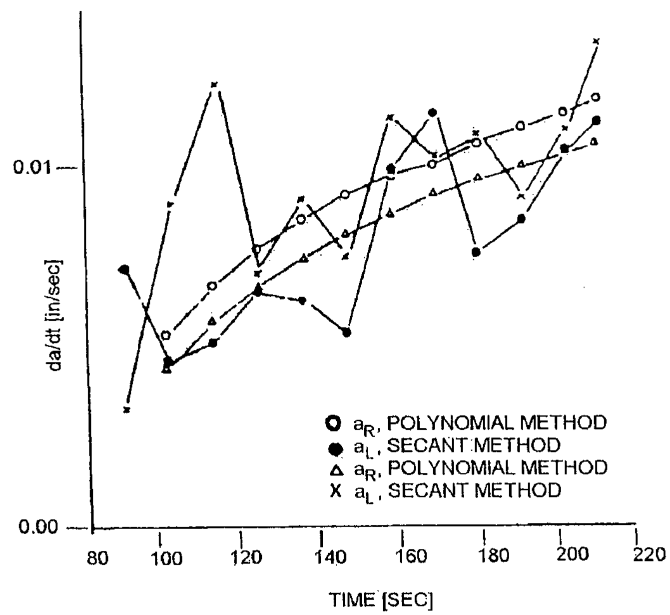
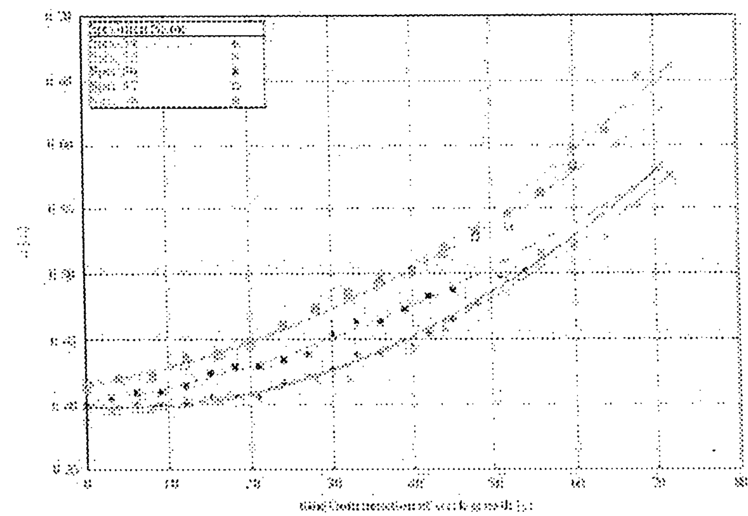




Results and Discussion

- Specimen Geometries (SENT, biaxial, surface cracked)
- Pressure Effects

Comparison of Biaxial and SENT Specimen Growth Data

Introduction

Experimental Procedure

Results and Discussion

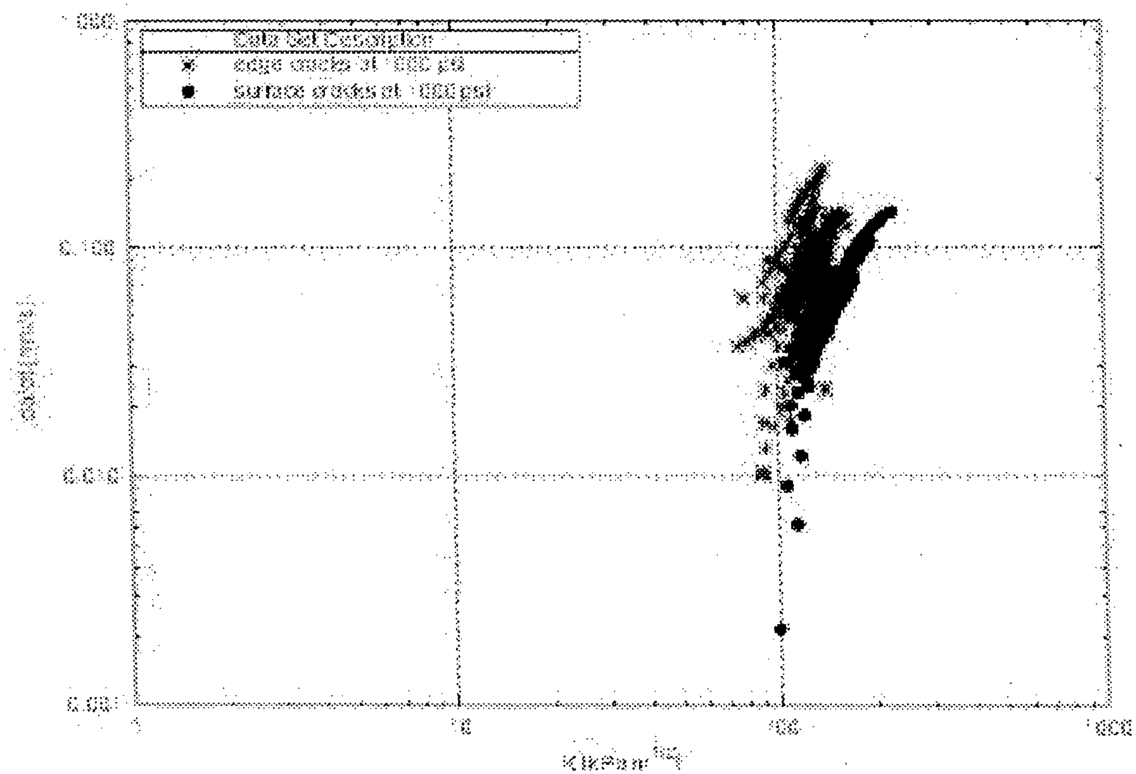
Summary and Conclusions

$$\frac{da}{dt} = C_1 K_I^{C_2} \quad \text{or} \quad \log\left(\frac{da}{dt}\right) = \log(C_1) + C_2 \log(K_I)$$

			da/dt (in/sec)	
Specimen type	$\log(C_1)$	C_2	$K_I = 50$ psi in$^{1/2}$	$K_I = 90$ psi in$^{1/2}$
SENT	-6.030	2.084	0.0028	0.0110
Biaxial	-6.590	2.375	0.0032	0.0113

SENT and Surface Cracked Specimen Comparisons

- Similar growth rates found for both geometries
- Implication: SENT data can be used instead of testing with surface cracked specimens



Ambient Vs. Pressurized Conditions

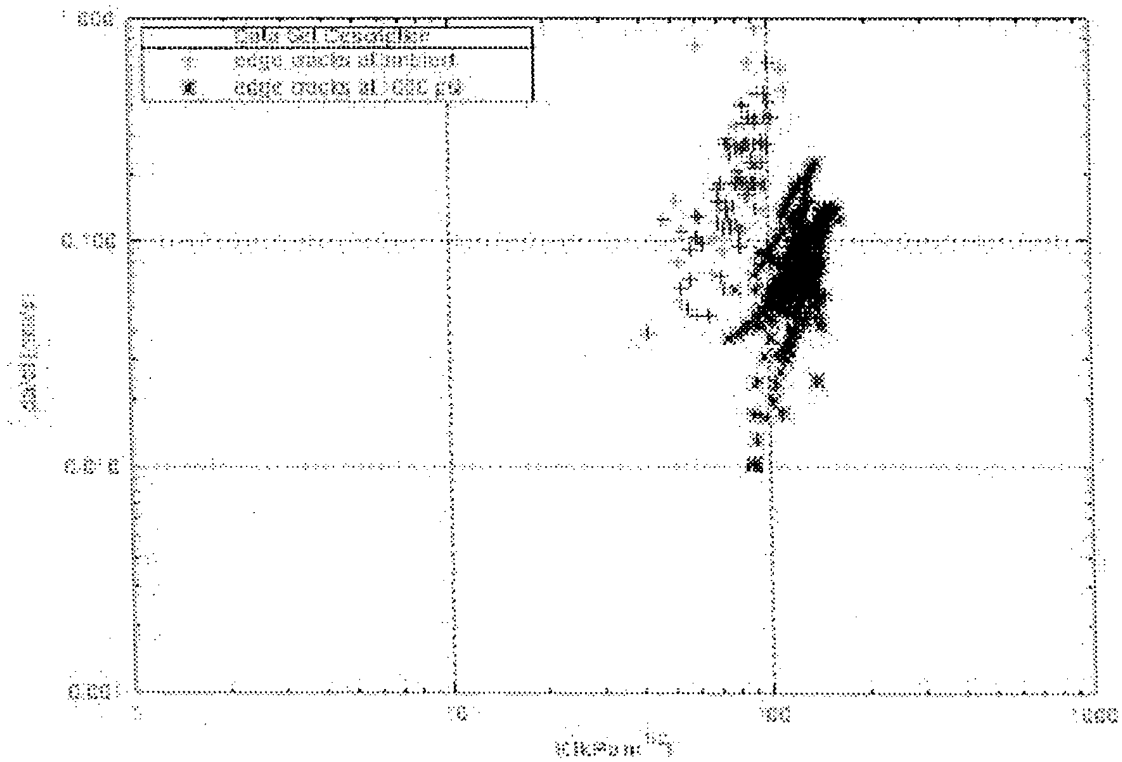
Introduction

Experimental Procedure

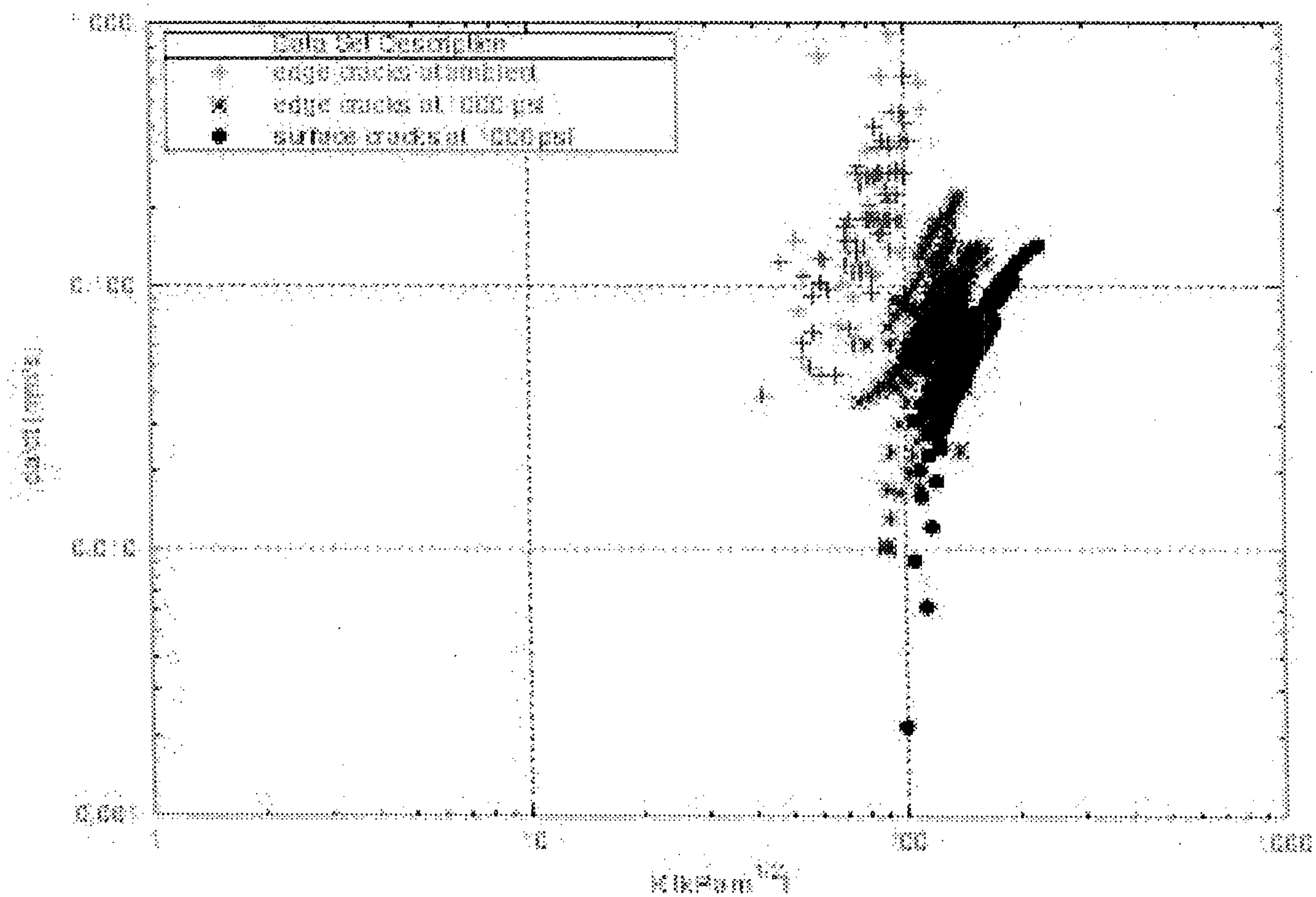
Results and Discussion

Summary and Conclusions

- Pressure causes crack growth to slow
- Microstructural explanation
- Implication: ambient data may be overly conservative for



Combination of Data



Summary and Conclusions

- Summary: this work has investigated the effect of pressure on fracture behavior of a rubbery particulate composite, and has compared the results for different crack geometries and different pressure conditions. Pressure delays the onset of crack growth and slows the subsequent growth rate. The results for the specimen geometries tested (both at ambient and 1000 psi (6895 kPa) pressure) show good agreement.
- Conclusions:
  - Good agreement between biaxial, SENT, and surface cracked specimens
  - Pressure inhibits the start of crack growth and slows the subsequent crack growth
  - Pressurized test data should be used to test for pressurized service conditions